4.0 Sewer System Evaluation Study

4.1 Overall Description

The Low Level Collection System Evaluation and Sewershed Plan, City of Baltimore Project No. 1029 consists of a wide range of activities as defined by the Consent Decree (CD). The testing and inspection of the wastewater collection system in what is termed sewer system evaluation survey (SSES) is a significant part of the overall evaluation of the sewershed. These SSES activities include conducting flow monitoring and rainfall data collection programs; completing the inspection of manholes and other sewer structures located within the collection system; completing CCTV and sonar inspections of sewers 8-inches in diameter and larger; conducting smoke and dyed-water testing; the preparation, calibration and validation of a hydraulic model; the identification of critical sewer system components within the collection system; and establishing criticality ratings for these components. All data was compiled to formulate a long-term rehabilitation and corrective action plan that includes an implementation schedule and estimates of probable costs.

The content and structure of the SSES program and report format has been established by the City. The City has provided guidance and general direction to the sewershed consultants to assure that all tasks completed in support of this study are prepared in a standardized format to facilitate the collection and review of the data for compliance with the requirements of the CD. Each of the eight (8) sewersheds in the City will be studied with emphasis on the inspection of sanitary sewers 8-inches and larger in diameter, including all sewer structures per Paragraph 9 of the CD. This information will be used in the preparation of a comprehensive corrective action plan for the sewershed. The joint venture of Hazen and Sawyer, Patton Harris Rust & Associates, and Hatch Mott MacDonald was tasked with the study and evaluation of the Low Level Sewershed.

The Low Level Sewershed is one of eight individual sewersheds located within the City of Baltimore. The Low Level Sewershed includes approximately 13.3 square miles of contributing area in the downtown central business area and adjacent harbor areas. The study area includes approximately 90 linear miles of 10- to 84-inch diameter gravity sewer (with an additional 175 linear miles of sewers less than 10 inches), 8,600 manholes and structures, and 3 main sewage pumping stations.

The sewers inspected per the CD ranged in size from small 8-inch diameter collector sewers to large 84-inch diameter interceptor sewers. The entire Low Level collection system is conveyed to the Eastern Avenue Pumping Station by two interceptor sewers (East and West) where the total flow is pumped into the Main Outfall Interceptor. All sewage collected in the Low Level sewershed is eventually conveyed to and treated at the City's Back River Wastewater Treatment Plant (WWTP).

4.2 Manhole Inspections

Manholes are the principal means to access a collection system. As such, effective manhole inspection is important in characterizing the overall condition and connectivity of the collection system. The manhole inspections completed for this project typically served multiple roles, which included characterizing the condition of the structure, identifying system connectivity, assisting in defining the general condition of the sewer segments connected to the structure, providing defect observation data required for the condition assessment and development of subsequent repair recommendations for the structure, and identifying additional potential sources of Inflow and Infiltration (I/I) into the collection system. The inspections also provided updated system attribute data such as pipe diameters, structure type and depths, network connectivity, and sewer system configuration. Collection of this data during the detailed inspections also allowed the City's GIS to be updated accurately and efficiently. These updates included removing structures that were originally identified as sewer structures in the GIS system but were actually not, and accurately updating the GIS with newly identified sewers and sewer structures that were not originally shown in the GIS.

Manholes were inspected as required by the CD in accordance with general guidelines outlined in the Environmental Protection Agency's (EPA) SSES Handbook, the American Society of Civil Engineers (ASCE) Manhole Inspection and Rehabilitation Manual 92, and the newly defined requirements of the National Association of Sewer Service Companies (NASSCO) Manhole Assessment and Certification Program (MACP). For the safety of the crews, a remote infrared manhole inspection camera was utilized to inspect and view defect images and observations in lieu of manned-entry to complete the majority of the inspections. All inspections were completed under the guidance of MACP certified inspectors. Manholes that could not be located or opened for inspection were documented for additional action. These structures will be inspected and incorporated into the City's overall rehabilitation plan.

The infrared manhole inspection camera used for the inspections allowed the inspector to visually observe the complete interior of the manhole or structure, including all incoming and outgoing pipes, and clearly identify defects. In certain circumstances, physical manned-entry internal inspections were required. When these were conducted, all entries were carried out in accordance with OSHA's 29 CFR 1910.146 Confined Space Entry Requirements.

To standardize the collection of the manhole inspection data, the Joint Venture utilized a specialized computer program called Manhole Inspection Application Software (MIAS). MIAS allowed field crews to collect detailed inspection information about the physical characteristics of a manhole or structure, identify any sewer connections to the structure and record details about the environment surrounding the manhole that was needed to accurately characterize the condition of the manhole or structure. In addition to the characteristics of the structure, such as the structure's size, shape and construction material, the MIAS application allowed defects and potential sources of I/I to be recorded. MIAS was designed to provide internal methods that link the inspection photographs of the manhole or defect observations to the manhole database record, making them available for easy review and preparation of formal reports to the City or for review at a later date. MIAS also allows access to the GIS and aerial maps, which provided the inspector with additional system or location information in the field to allow them to accurately complete the inspection and update the detailed inspection database.

The following is a brief description of the process involved in the collection of manhole inspection data for the Low Level Sewershed. The following descriptions are not intended to cover all aspects of the work performed, rather to provide the reader with a general understanding of the data collection and review process.

- A manhole inspection crew consisting of two inspectors uses a 1" = 100' scale GIS map to identify manholes to be inspected. This map contains information such as street names, manhole location and ID, flow direction and connectivity of the system with all other upstream and downstream manholes.
- The crew selects a manhole from the database list of manholes and goes to the location where the manhole is shown on the GIS map and performs a visual search in an effort to locate the manhole or structure for inspection. If found, the manhole is located utilizing GPS or other typical survey techniques such as triangulation measurements, and then the manhole is inspected. If the manhole is not found, the position is estimated based on the surrounding objects shown on the map and methods such as probing the soil are used to try to locate the manhole for inspection.
- If a manhole structure is not found after field investigation or cannot be opened, it is noted as "Cannot Locate (CNL)" or "Cannot Open (CNO)" in the MIAS database and forwarded to City maintenance for locating and opening. Once the manhole is made accessible, the inspection team is notified and they revisit the site and complete the inspection.
- Once a manhole is located and opened, the MIAS survey is completed. The format of the MIAS inspection form prompts the inspector to begin their inspection by recording features such as the structure's location, then features and defects are recorded starting at the top of the manhole structure and working down to the invert. These entries include frame/cover type, condition, and materials of construction for the chimney, corbel, barrel, bench and channel and their current condition and evidence of I/I.
- Photographs are obtained and entered into the system for location views and top down views of the manhole; photographs are also collected for the pipe connections and any significant defects when possible.
- Pipe connections are recorded and located according to clock position with the outgoing pipe always being the 12 o'clock position. Pipe diameter and rim to invert depths are also collected and recorded in MIAS along with the condition of the pipe seals.
- All manholes are then assigned a 1-5 condition rating, with 1 being in excellent condition and 5 being in very poor condition and requiring immediate attention.

As the means for prioritizing the maintenance and repair of the manholes, a condition rating scale was used to weight the various types of structural defects and I/I conditions that occurred in different components of the manhole structure. This rating system also allowed for the characterization of operation and maintenance (O&M) type issues such as identification of fats, oils and grease (FOG), debris accumulations, surcharging of the manhole and other O&M type issues. During the initial phase of this project, NASSCO introduced a standard for manhole condition assessment. This standard was the Manhole Assessment and Certification Program (MACP), which was subsequently adopted by the City to aid in the consistency of data collected and to provide for a reliable evaluation of each manhole component. The use of this standard provides a baseline condition assessment of the structure, which aids in providing a consistent

review of conditions during future inspections. The 1-5 condition rating standard used for the manhole inspections is largely based on the ASCE Manual of Practice No. 92, which utilizes a 5-point severity rating system. The following represents the rating scale:

1. **Excellent Condition** – Only minor defects
2. **Good Condition** – Defects have not started to deteriorate
3. **Fair Condition** – Moderate defects that will continue to deteriorate
4. **Poor Condition** – Severe defects likely to become a grade 5
5. **Immediate Attention Required** – Defects requiring immediate attention

Table 4.2.1 provides an overview of the condition of the 6,499 manholes inspected to-date as part of the Low Level Sewershed manhole inspection program and classifies the manholes by overall structure rating. Table 4.2.2 summarizes the total number of defects observed, classifying the conditions by defect type. Table 4.2.3 shows the incidence of infiltration defects and where those infiltration defects are located within the manhole. Attachment 4.2.1 contains the manhole inspection database and all manhole inspection reports completed for this project.

Table 4.2.1 – Manhole Condition Summary

Overall Rating	Count	%
1: Excellent Condition	84	1.29%
2: Good Condition	707	10.88%
3: Fair Condition	5,121	78.80%
4: Poor Condition	454	6.98%
5: Immediate Attention Required	133	2.05%
Manholes Inspected:	**6,499**	

Table 4.2.2 – Manhole Defect Location Summary

Manhole Inspection Defects	
Component	**Quantity**
MH Cover Defects	263
MH Frame Defects	1,044
MH Chimney Defects	5,659
MH Corbel Defects	1,738
MH Barrel Defects	1,413
MH Bench Defects	2,988
MH Channel Defects	1,969
MH Pipe Defects	2,149
Pipe Seal Defects	10,795
MH Steps	4,952
Total Defects:	**32,970**

Table 4.2.3 –Manhole Infiltration Location Summary

Count	Percent	Description
6,499		Total Manholes Inspected
4,327	66.58%	Manholes that Leak
859	13.22%	Frame Leaks
3,685	56.70%	Chimney Leaks
1,111	17.09%	Corbel Leaks
1,179	18.14%	Barrel Leaks
14	0.22%	Bench Leaks
7	0.11%	Channel Leaks

4.3 Sewer Cleaning and Closed Circuit Television Inspection

CCTV inspection of sewers is the process of remotely internally inspecting and documenting the condition of conveyance pipes. It also provides valuable insight into the cleaning and maintenance requirements of each sewer segment and provides information that is needed to assign appropriate rehabilitation technologies to deteriorated or damaged pipe segments.

Sewer Cleaning: To provide the highest visibility of defects all sewers inspected were cleaned prior to inspection to accurately define the conditions. Sewers were cleaned utilizing hydraulically propelled high-velocity jet or other mechanically powered equipment. The intent of the cleaning operations was twofold. First, to adequately clean the sewer so the inspection could identify defects that otherwise would not be visible and second, to remove all foreign materials from the sewer to restore the sewer to a minimum of 95% of its original capacity. Special emphasis was placed on this phase of work because the success of the other phases depended on it.

When heavy debris was encountered, heavy cleaning was utilized to restore the capacity of the sewers and allow for internal inspection. Heavy cleaning involved additional passes of the hydro-cleaning equipment, up to a total of eight passes. To the extent feasible, all debris was removed from the sewers. When significant blockages were identified, they were reported to the City.

Sewer Inspection: Following cleaning, the sewer segments were inspected by means of closed-circuit television (CCTV) inspection. These inspections were used to identify the following:

- Condition of current pipes including existing or potential structural deficiencies or problems, and accurately identifying the pipe's connectivity and location.
- Confirmation, extent and current condition of previous rehabilitation projects and/or repairs.
- Identification of improper or potentially illicit connections.
- Identification of potential sources and extent of segment I/I.
- Assist in selecting appropriate methods of repair, rehabilitation and/or replacement.

Paragraph 9 of the CD requires that gravity sewers eight (8) inches and larger in diameter be inspected using CCTV inspection in accordance with NASSCO guidelines. The CCTV inspection of the sewers provided the necessary condition assessment for the SSES evaluation of the Low Level Sewershed. The inspections identified defects and other problems relating to the sanitary sewer collection and conveyance system that allows the project team to compile a comprehensive corrective action plan and prioritize an implementation schedule.

All CCTV inspections were completed and data collected according to NASSCO's Pipeline Assessment and Certification Program (PACP) guidelines and standards. The City required the use of PACP certified software to collect and record all CCTV information. All CCTV operators, and reviewers were certified in the use of the PACP coding system.

All CCTV inspections were conducted using a color pan-and-tilt, radial viewing inspection camera that provides adequate illumination to clearly observe defects and other features within the pipe. All sewers were cleaned before being televised in order to capture the most accurate and complete depiction of defects and features. Whenever possible, surveys were initiated from the upstream manhole proceeding downstream with the flow to minimize splashing of the camera. When defects or other obstructions prevented the completion of the inspection in this direction, a reverse inspection was initiated from the downstream manhole to complete the inspection of the sewer segment. The CCTV camera lens was required to be positioned in the center of the pipe being inspected and movement of the camera through the sewer pipe did not exceed a speed of 30-feet per minute. Wastewater flows in the sewer during the inspection were controlled and did not exceed 20 percent of the pipe capacity for pipes 8"- 10"; 25 percent for pipes 12"- 24", and 30 percent for pipes 24" and larger per the PACP guidelines. During the internal inspection, the CCTV camera was temporarily stopped at all significant defects and side sewer or service connections to accurately code and provide a clear image of the defect or point of connection. For larger sewer inspections where it was not practical or when flows could not safely or effectively be reduced, sonar inspection or a combination of sonar and CCTV inspection was used to inspect the sewers. The use of a combination CCTV/sonar camera allowed for the visual inspection of the sewer above the flow line and the sonar provided inspection information below the flow of the sewer.

As a means to prioritize the maintenance and repair of pipe sections and other associated sewer appurtenances, a condition rating scale was used to rate the various types and degrees of structural defects and I/I conditions occurring in different segments of the sanitary sewer system. The PACP rating scale was utilized as a standard and consistent format for the way pipes were evaluated and conditions recorded. These standards allow pipe conditions to be reported in a standard recognized manner and allow the City to compare the segment's condition from one time frame to another and accurately track the condition of the pipe and any progression of defects.

The PACP coding system requires the assignment of a specific code for each structural and O&M type defect identified within a pipe segment. The software automatically assigns a PACP rating code to each defect when entered. These grades are assigned based on the potential for further deterioration or possible failure of the pipe.

The PACP grading system obtained from NASSCO's "Pipeline Assessment and Certification Program" reference manual utilized for this project is as follows:

Grade	Description	Time to Failure
5	Immediate Attention Required	Pipe has failed or will fail within 5 years
4	Poor	Pipe will probably fail within 5 to 10 years
3	Fair	Pipe may fail in 10 to 20 years
2	Good	Pipe unlikely to fail for at least 20 years
1	Excellent	Failure unlikely in the foreseeable future

Utilizing this system, each pre-defined defect or observation code is directly associated with a severity rating based on the type and extent of the defect. These ratings aid in determining the need for maintenance, repair, rehabilitation or replacement of the pipe segment. The PACP software assigns a four-digit severity code, or PACP quick rating for each sewer segment inspected and contained in the database. These ratings, in conjunction with the criticality rating of the system component were used to prioritize system repairs.

Tables 4.3.1 and 4.3.2 summarize the defects recorded during the CCTV inspections by type of defect and by structural condition rating, respectively. Table 4.3.3 summarizes the O&M condition ratings. Attachment 4.3.1 contains all CCTV inspection information completed to-date as part of the CCTV inspection program in the Low Level Sewershed.

Table 4.3.1 – CCTV Defect Observation Summary

CCTV Inspection Defects		Pipe Size (inches)					Total
Family	Group Type	8"- 12"	14"- 18"	20"- 33"	36"- 56"	>60"	
Structural	Break in pipe	2,709	75	27	53	2	**2,866**
Structural	Collapse	59	0	0	1	0	**60**
Structural	Cracks	27,428	897	764	49	0	**29,138**
Structural	Fracture	8,536	550	201	4	0	**9,291**
Structural	Deformation	119	10	3	0	0	**132**
Structural	Defective Joints	13,713	407	22	0	0	**14,142**
Structural	Defective Lining	100	59	133	15	47	**354**
Construction	Defective Taps	13,934	195	83	5	5	**14,222**
O&M	Roots	10,270	164	309	153	4	**10,900**
O&M	Grease	23,221	1,063	1,107	482	524	**26,397**
O&M	Encrustation & Scale	23,407	1,036	2,843	314	46	**27,646**
O&M	Settled Deposits	6,399	1,166	1,424	0	1	**8,990**
O&M	Infiltration	1,550	187	1,017	295	37	**3,086**
O&M	Obstruction	1,810	159	461	8	3	**2,441**
Construction	Line Deviations	402	13	60	29	13	**517**
Miscellaneous	Water Level +20%	8,269	457	254	43	42	**9,065**
Miscellaneous	Survey Abandoned	1,902	137	112	2	3	**2,156**
Miscellaneous	Camera Underwater	297	10	37	2	1	**347**
		144,125	**6,585**	**8,857**	**1,455**	**728**	**161,750**
		89.10%	**4.07%**	**5.48%**	**0.90%**	**0.45%**	

Table 4.3.2 – Sewer Structural Condition Rating Summary

Rating	Segments	Percent	LF
5 - Defects that require immediate attention	50	0.5%	12,445
4 (Poor) – Severe defects that will become grade 5 in the near future	38	0.4%	8,849
3 (Fair) - Moderate defects that will continue to deteriorate	120	1.3%	25,544
2 (Good) - Minor defects that have not started to deteriorate	613	6.6%	97,011
1 (Excellent) – No defects or minor defects present	8,413	91.1%	948,123
Total:	**9,234**	**100.0%**	**1,091,972**

Table 4.3.3 – Sewer Operation and Maintenance Condition Rating Summary

Rating	Segments	Percent	LF
5 - Defects that require immediate attention	66	0.7%	16,417
4 (Poor) – Severe defects that will become grade 5 in the near future	107	1.2%	23,640
3 (Fair) - Moderate defects that will continue to deteriorate	263	2.8%	56,219
2 (Good) - Minor defects that have not started to deteriorate	1,079	11.7%	176,115
1 (Excellent) – No defects or minor defects present	7,719	83.6%	819,580
Total:	**9,234**	**100.0%**	**1,091,972**

4.4 Force Main Inspections

4.4.1. Eastern Avenue Pumping Station Force Mains

There are three force mains originating at the Eastern Avenue Pumping Station that carry flow to the Outfall Sewershed. Two of the force mains are comprised of twin 42-inch cast iron force mains, identified as “north” and “south”, which were lined in 2002 effectively reducing their diameter to 36-inches. The third force main is a 60-inch force main was constructed in late 1970’s. Pumping station personnel indicated flow is normally discharged through the 60-inch force main with flow being discharged through the twin 36-inch force mains during high flow and emergency conditions.

In December 2007, the three force mains were sonar inspected to characterize the silt levels with the inspections started at the force main discharge chamber at the intersection of North Bond and East Fayette Streets and proceeded upstream until cable drag and pipe bends prevented further movement of the sonar rig. The north and south twin 36-inch force mains were inspected for 2,507 feet and 3,351 feet, respectively with the 60-inch force main being inspected for 3,741 feet. Silt ranging in depth of 3 to 8 inches was detected in the north 36” force main for a distance of about 500 feet from the force main discharge chamber. The south 36-inch and the 60-inch force mains both had smaller amounts of silt, with the silt level never exceeding 3 inches.

4.4.2. Locust Point and McComas Street Pumping Station Force Mains

As of the writing of this report, the design of a replacement for the 10-inch Locust Point Force Main and is currently being bid for construction. Based upon the construction of a replacement force main for Locust Point it was elected not conduct an inspection of this force main. The McComas Street Force Main is 6-inches in diameter which the Low Level Scope of Work excludes the inspection of pipes that are less than 8-inches in diameter and was not inspected.

4.4.3. Grinder Pump Force Mains

Grinder Pump Stations No. 1, 2, 3, 5 and 7 are connected in series (Grinder Pump Stations No. 4 and 6 do not exist) and pump flow from low-lying house connections along South Clinton Street via small diameter PVC force mains to the gravity system at the intersection of South Clinton Street and Holabird Avenue.

The Insulator Dr Grinder Pump Station pumps flow via a 2-inch PVC force main to the gravity system just south of the intersection of Insulator Drive and East Cromwell Street.

All of the PVC force mains associated with the Grinder Pump Stations are less than 6-inches in diameter and are excluded from inspection as defined by the project Scope of Work. Table 4.4.1. Summarizes force mains within the Low Level Sewershed.

Table 4.4.1 - Low Level Sewershed Force Main Summary

Force Main	Diameter (inches)	Length (ft)	Inspection Status
Eastern Avenue Pumping Station Force Mains			
Eastern Ave. 60" Force Main	60	4,500	Sonar inspected
Eastern Ave. 36" Force Main (North)	36	5,500	Sonar inspected
Eastern Ave. 36" Force Main (South)	36	5,500	Sonar inspected
Smaller Pumping Station Force Mains			
Locust Point	10	2,900	To be replaced
McComas Street	6	900	Out of scope
Grinder Pump Force Mains			
Grinder Pump Station #1	3	2,300	Out of scope
Grinder Pump Station #2	3	430	Out of scope
Grinder Pump Station #3	3 – 4	220	Out of scope
Grinder Pump Station #5	4	1,100	Out of scope
Grinder Pump Station #7	4	120	Out of scope
Insulator Dr Grinder Pump	2	350	Out of scope

4.5 Smoke Testing

Smoke testing was utilized by the project team as a means to quickly and effectively identify potential locations of stormwater/groundwater entry into the sanitary sewer collection system. Direct connections including downspouts, area drains, driveway drains, stairwell drains, patio drains, and storm sewer inlets or ditches can be confirmed with smoke testing. Indirect connections from storm sewers or drainage ditches, which allows I/I to pass through soil and into deteriorated or damaged conveyance piping, can also be identified with smoke testing.

The smoke testing operations for this project were conducted between July and September 2008, during periods when the groundwater table was low and with sufficient time having elapsed from any prior rain events. Smoke testing was not allowed to be completed until 24-hours had passed from a wet-weather event to make sure the soils were sufficiently dry to allow detection of smoke. Prior to initiating the smoke testing, an extensive list of property owners, hospitals, nursing homes, schools, daycares, local civic and community leaders, community associations, council members, and police and fire officials were notified. This process included monthly testing notifications and the distribution of detailed smoke testing door hanger notifications, typically extending two blocks outside the test areas three days prior to conducting the tests. When smoke testing was initiated and subsequently stopped because of rain, re-initiation of the testing did not occur until conditions were again suitable and the notification

process was completed again. In most cases, smoke testing was conducted using a single blower setup technique with theatrical smoke being introduced at the smoke blower and pushed through isolated sections of the pipe. The maximum allowable set-up length was no more than two total manhole reaches. A manhole reach is defined as a manhole to manhole segment of the sewer.

Field crews were responsible for determining that adequate smoke coverage was obtained by observing smoke concentrations. Smoke was continually introduced into the test setup until adequate smoke coverage was obtained in the test area. In the event that smoke did not travel the entire reach, the setup was reversed by setting the blower on the opposing manhole of the initial setup and re-introducing the smoke. Such situations were often caused by pipe sags that contained flow, grease, debris, collapsed pipes, or other obstructions that would prevent smoke from traveling through the pipe. All instances were documented as a potential maintenance problem and reported to the City.

Both the upstream and downstream manholes were isolated during the smoke testing to concentrate the smoke within the test section. These restrictions were accomplished using sandbags or air plugs. In situations where heavier smoke concentrations were required, a higher concentration of smoke was simply introduced into the sewer for an extended period of time. The maximum set-up length in this situation was typically limited to 1,000 LF, however because of field conditions, this length was extended. Potential sources of “clear water” connections (such as catch basin connections) were noted and were recommended for follow-up dyed-water testing to determine if actual cross connections existed. Care was taken to inspect the property around all buildings for sources of smoke. In situations where heavy smoke exited a source and it could be determined and documented through observation that the source was directly connected to the sanitary sewer, further investigation was not necessary.

Table 4.5.1 summarizes the defects identified during the smoke testing inspections, identified by type of defect or source, defect location and the sector (public or private). Attachment 4.5.1 contains all smoke testing inspection data completed for this project.

Table 4.5.1 – Smoke Testing Defect Summary

Code	Sector	Total Defects	%
01	Public	114	22
02	Private	179	78
	Total:	**293**	
Code	**Source Type**	**Total Observations**	**%**
01	Main Sewer	29	9.9
02	Service Line	47	16.0
03	Cleanout	96	32.8
04	Downspout	3	1.0
05	Area Drain	7	2.4
06	Driveway Drain	0	0
07	Stairwell Drain	0	0
08	Foundation Drain	0	0
09	Building Interior	12	4.1
10	MH Frame Seal	70	23.9
11	Storm Drain	0	0
12	Catch Basin/Inlet	12	4.1
13	Storm Manhole	0	0
14	Storm Ditch	0	0
15	Excavation	1	0.3
16	Water Line	0	0
17	Telephone Pole	4	1.4
18	Other	12	4.1
	Total:	**293**	

Defect items in Table 4.5.1 that were coded as 05 – Area Drains and 12 – Catch Basin/Inlet, were scheduled for additional investigation utilizing dyed-water testing.

4.6 Dyed-Water Testing

The dyed-water testing of areas identified in Table 4.5.1 such as storm drain catch basins were conducted as part of the study of the Low Level collection system. Dyed-water tests were also conducted in LL-19 at seven locations. Because of the two existing detention centers and associated facilities in the western portion of the sewershed, smoke testing was not performed. The dyed-water test aided the project team in detecting pipe segments that were either direct or indirect connections between the storm drain and sanitary sewer system. Direct connections were typically confirmed during the smoke testing operations; however, any suspect locations were further investigated using dyed-water testing. To complete this testing, the suspect catch basin or area drain was flooded with dyed-water and the adjacent connecting sanitary sewer manholes were observed for the presence of dye in the flow.

Table 4.6.1 summarizes the tests by location and type, and identifies all defects observed during the dyed-water testing inspections. Attachment 4.6.1 contains all dyed-water tests completed as part of this project.

Table 4.6.1 – Dyed-Water Testing Defect Summary

Code	Sector	Total Defects	%
01	Public	1	25.0
02	Private	3	75.0
	Total:	**4**	
Code	**Source Type**	**Total Observations**	**%**
01	Main Sewer	0	0
02	Service Line	0	0
03	Cleanout	0	0
04	Downspout	0	0
05	Area Drain	3	75.0
06	Driveway Drain	0	0
07	Stairwell Drain	0	0
08	Foundation Drain	0	0
09	Building Interior	0	0
10	MH Frame/Seal	0	0
11	Storm Drain	0	0
12	Catch Basin/Inlet	1	25.0
13	Storm Manhole	0	0
14	Storm Ditch	0	0
15	Excavation	0	0
16	Water line	0	0
17	Telephone line	0	0
18	Water line	0	0
	Total:	**4**	

As shown in Table 4.6.1, four defects were identified during the dyed-water testing. The CCTV survey records performed in the vicinity of the four defects were reviewed to determine if the defects were illegal connections. The existence of illegal connections was not observed in the CCTV surveys and the defects are considered to be indirect connections.

4.7 Emergency Repairs / Rehabilitation

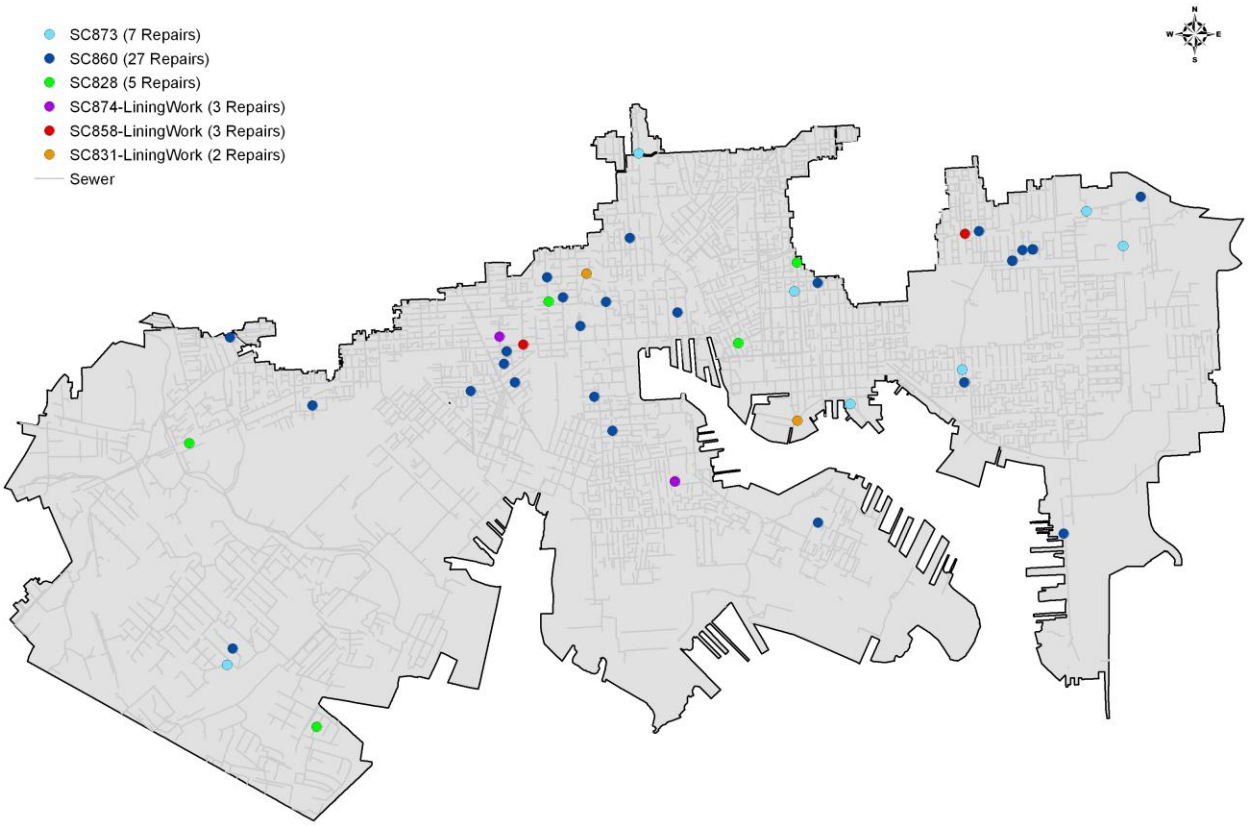
In accordance with the requirements of Paragraph 9 C (iii) of the CD, which states “Identify all rehabilitation or other corrective actions taken by Baltimore (including but not limited to grouting, point repairs, liner replacement) to address the deficiencies identified during evaluation of the sewershed.”

In support of this effort, the project team reported all significant system defects observed during field inspections or when reviewing the collected data as part of the sewer evaluation phase.

Upon discovery of these deficiencies, the information was compiled and detailed maps, CCTV video and photographs were provided to the City. In some cases, the City's non-emergency assistance hotline (311) was also contacted. In all cases, the City promptly coordinated with the wastewater maintenance division or their on-call contractor to resolve the deficiencies.

The resolution of the work was prioritized based on on-going repair work being performed within the City and the severity of the deficiency discovered (emergency or priority). As the City-wide evaluation survey continues, new deficiencies will be identified and reported to the City. To date, the City has completed cured-in-place (CIPP) lining of 8 locations and has made 39 point repairs within the Low Level sewershed. Figure 4.7.1 shows the spatial locations of these repairs by sanitary contract number.

Figure 4.7.1 - Sanitary Repairs performed in the Low Level Sewershed (January 2006 to March 2009)



4.8 Pumping Station Evaluations

Pumping stations are a component of the Low Level collection system. The Low Level Sewershed includes one major pumping station, the Eastern Avenue Pumping Station, which is undergoing a control system upgrade to better utilize the existing pumps, and two smaller pumping stations; the Locust Point Pumping Station and the McComas Street Pumping Station. Details of these stations are described below.

The **Eastern Avenue Pumping Station** is located at the intersection of Eastern Avenue and South President Street, to the east of Pier 6 in the Inner Harbor area, and was originally constructed in 1912. However, the existing pumps, motors and electrical equipment were installed between 1959 and 1961. More recently, major structural and architectural renovations, and improvements to the ventilation system were completed under Sanitary Contract 571. Additional modifications were completed under Sanitary Contract 641, which primarily included replacing the manually cleaned bar screens with mechanical screens, the construction of screenings handling facilities, and the installation of a new standby generator. The station contains 6 pumps. Five are connected to the force main system, which discharges through a 60-inch diameter force main to a 99-inch diameter gravity outfall to the Outfall Sewershed. The sixth pump is an emergency relief. This latter pump discharges directly to the harbor. The safe capacity of the pumping station is 117 MGD and the maximum capacity is 133 MGD.

The **Locust Point and McComas Street Pumping Stations**, constructed in 1977 and 1980, respectively, are two smaller pumping stations (1.8 and 0.7 MGD respectively) that convey flow towards the Eastern Avenue Pumping Station. Both pumping stations are unattended. Each is equipped with remote monitoring alarm systems indicating pumping malfunctions and high or low wet well water levels. The Waste Water Facilities Division monitors these alarms 24 hours a day at the Eastern Avenue Pumping Station.

4.9 Data Quality Assurance / Quality Control Procedures

The following sections provide the reader with a brief description of the Quality Assurance / Quality Control (QA/QC) review process that all inspections underwent before they were considered complete and delivered to the City. In addition, copies of the Manhole Condition Rating and Defect Manuals, CCTV Review Manual and Smoke and Dyed-Water Testing Procedures Manuals developed by the Joint Venture to ensure the consistency and accuracy of the data being provided to the City are included as Attachments 4.9.1 through 4.9.4 of this report.

4.9.1 Manhole Inspection QA / QC Procedures:

- MIAS contains several internal field checks, which prompt the inspector to verify information as it is entered. (e.g. if an inspector enters the invert elevation of an outgoing pipe at a higher elevation than the incoming pipe's invert elevation, the check prompts the inspector to verify the information). Several of these internal checks will not allow the inspector to move on to the next entry item in the inspection until the prior inspection item has been successfully completed.

- Basic information regarding location and system connectivity was compared with existing information or contract documents. Connecting manhole nodes entered in MIAS were compared to what was shown on the mapping and corrections made as necessary.
- All information was reviewed, which included reviewing for errors, assuring photograph quality and reviewing all comments entered by the inspector for clarity and content.
- If there was information missing, the MIAS record was failed and returned to a field crew to revisit the site and collect the required information or the reviewer would utilized existing record documents to obtain the required information.
- When the follow-up information was collected by the field crew or addressed by the reviewer utilizing record data, the new information was again reviewed and if acceptable, added to the record. The record was then tagged as QA/QC complete and flagged for submittal to the City.

4.9.2 CCTV Inspection QA / QC Procedures:

- Review all CCTV inspections for conformance with PACP coding guidelines (video quality, flow levels, header information, all defects coded, and coded properly).
- Review all CCTV footage and inspection logs for significant defects such as collapsed pipe, blockages, etc. and forward these defects to the City for action.
- Review CCTV footage and inspection logs for significant O&M items such as excessive grease, roots, etc. and forward these defects to the City for action.
- If issues were found with video quality or PACP coding of defects for the segment inspected, the inspection record was returned to the CCTV contractor with review comments for recoding or re-surveying.

4.9.3 Smoke Testing QA / QC Procedures:

- Review all completed field reports for conformance to the project guidelines and accuracy assuring that all maps, defect information and photographs are complete, clear, accurate and compatible.
- Review all smoke testing entries entered into the Access database to assure all observations and photographs are in accordance with the database scheme and specifications outlined for the project.
- Return if any field data that was questionable, incomplete or illegible, to the responsible contractor with review comments for correction and resubmission.
- Review all data submitted to identify significant defects such as cross connections. Any significant findings were reviewed and if required, assigned for further evaluation utilizing dyed-water testing.
- Submit any confirmed cross-connections or illegal connections to the City for follow-up action, and document them in the Sewershed Plan and Study Report.

4.9.4 Dyed-Water Testing QA / QC Procedures:

- Review all completed field data for conformance with the project guidelines and accuracy requirements assuring that all maps, defect information and photographs are complete, clear, accurate and compatible.
- Enter all dyed-water testing information into the Access database to assure all observations and photographs are in accordance with the database scheme and specifications outlined for the project.
- Return if any field data that was questionable, incomplete or illegible, to the responsible contractor with review comments for correction and resubmission.
- Submit any confirmed cross-connections or illegal connections to the City for follow-up action, and document them in the Sewershed Plan and Study Report.